

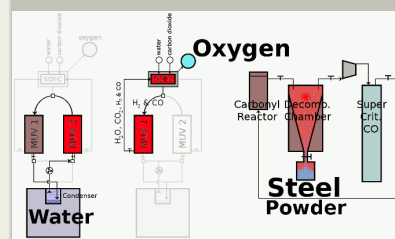
# Regolith to Steel Powder, Oxygen & Water with Small Equipment, Phase I

Completed Technology Project (2017 - 2018)



## Project Introduction

This proposal covers processing of raw Martian regolith to both an enriched iron ore and liberated water, and also iron ore reduction and oxygen production, metal purification and steel powder making. Our proposal uses heat re-cycling to improve the energy efficiency of both regolith-to-ore enrichment and iron ore reduction. This heat re-cycling creates a bonus, the liberation of water (formerly bound to the regolith) as liquid water and a relatively low temperature water vapor. This water can be retrieved with the addition of a small condenser unit and a water storage tank/heat sink. Iron (and other transition metal) oxides are reduced using a reducing gas mixture of hydrogen and carbon monoxide inside two multi-use vessels (MUVs, in which heat recycling is also done). The reduction makes metals, mostly iron, but also exhausts water and carbon dioxide. This exhaust is re-cycled to a water/carbon dioxide splitter that produces the hydrogen and carbon monoxide reducing gases and also oxygen. The preferred water/carbon dioxide splitter is a solid oxide electrolysis cell (SOEC) from Ceramtec (maker of the SOEC for NASA's MOXIE), and Ceramtec has asked to be included in the proposal with a budget placeholder as a supplier. Metal purification and steel powder making is done using carbonyl metallurgy techniques developed by BASF with a possible variation to replace steel powder making with metal vapor deposition to shaped steel objects (as previously advocated for by William Jenkins). It should be emphasized that the entire manufacturing chain, and an extended chain than includes 3D metal powder printing to finished steel objects, (i) can be operated by robots (that can also carry out ore mining), and (ii) the robots and equipment needed to carry out this mining and manufacturing chain can be made such that their entire combined total mass is small enough to fit in Mars landing craft payloads well under 2500 kg.



Regolith to Steel Powder, Oxygen & Water with Small Equipment, Phase I Briefing Chart Image

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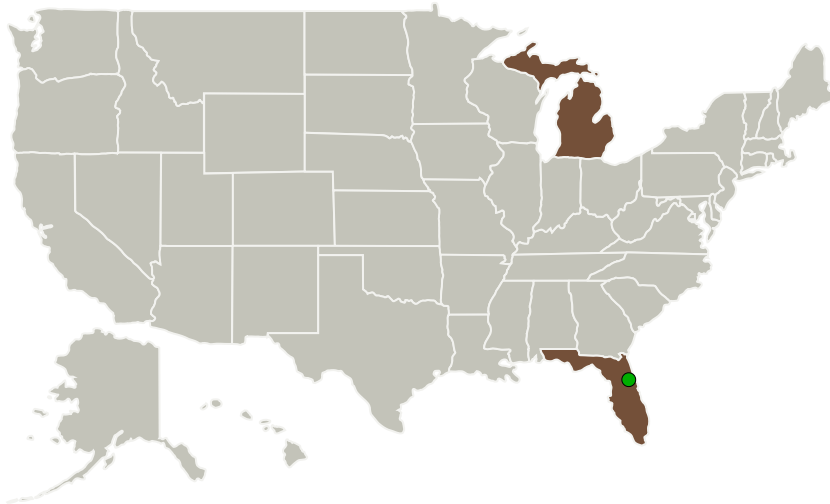
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## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Two Planet Steel	Lead Organization	Industry	San Diego, California
● Kennedy Space Center(KSC)	Supporting Organization	NASA Center	Kennedy Space Center, Florida
Michigan State University	Supporting Organization	Academia	East Lansing, Michigan

## Primary U.S. Work Locations

Florida	Michigan
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## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

Two Planet Steel

**Responsible Program:**

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

**Program Director:**

Jason L Kessler

**Program Manager:**

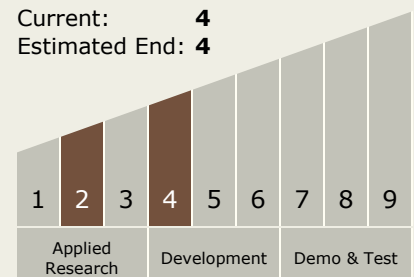
Carlos Torrez

**Principal Investigator:**

Rolf Olsen

## Technology Maturity (TRL)

Start: 2  
 Current: 4  
 Estimated End: 4

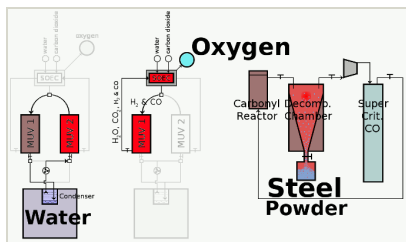


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## Images



### Briefing Chart Image

Regolith to Steel Powder, Oxygen & Water with Small Equipment, Phase I Briefing Chart Image

(<https://techport.nasa.gov/image/131168>)

## Technology Areas

### Primary:

- TX07 Exploration Destination Systems
  - └ TX07.1 In-Situ Resource Utilization
    - └ TX07.1.3 Resource Processing for Production of Mission Consumables

## Target Destinations

The Sun, Earth, The Moon, Mars, Others Inside the Solar System, Outside the Solar System